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Simulation and Computer Graphics

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Simulation and Computer Graphics

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PROLOGUE

In these four pages, this paper can be neither a complete introduction nor a complete survey of the role of computer graphics in simulation. However, these examples drawn from the experience of the Naval Post graduate School computer laboratory will illustrate a wide class of applications which may suggest uses in other fields. The interested reader should refer to the January 1971 issue of *SIMULATION* (which was devoted entirely to computer graphics applications in simulation) and to the supplementary reading list at the end of this paper.

INTRODUCTION

A computer simulation is the mechanization of a mathematical model in a manner designed for experimentation. The goal of simulation is to provide an understanding of the system being modeled, its sensitivity to parameter variations, and the effects of increasing complexity. The insight to be gained by simulation was first demonstrated by the close man-machine interface provided by hands-on use of analog computers. The advent of high-speed computer graphics brought a dramatic revolution in the man-machine interface. Today rapid computation and the display of solutions at rates comparable to a motion picture provide means to exploit the pattern-recognition properties of the eye and brain (especially useful in computer-aided instruction).

COMPUTER SYSTEMS FOR SIMULATION

Ideally a computing system intended for use as a simulator should provide on-line, hands-on, high-speed computation with excellent displays and interfaces to external hardware. While such a system can be composed in various ways, the NPS laboratory has met these demands with a multiprocessor hybrid system. It provides word-parallel data channels working at memory-cycle rates which interconnect four computers as shown in Figure 1. Modern digital computers are fast enough for most real-time applications, and graphics consoles and special simulation languages are rapidly removing the last barriers to all-digital simulations, except for certain stochastic systems and research in interaction *per se*.[1 2 3] Of all the attempts to combine the best properties of analog and digital machines by hybridization, perhaps the most exciting and most widely useful is the graphics terminal, a system which is a rather sophisticated special-purpose hybrid processor itself.

GRAPHICS APPLICATIONS

The use of dynamic interaction as a stimulus for insight is difficult to present without motion pictures. It

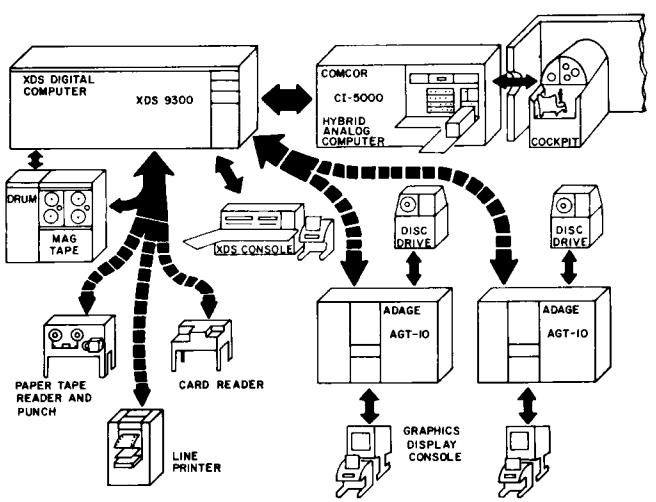

Figure 1 – Naval Postgraduate School Computer Laboratory

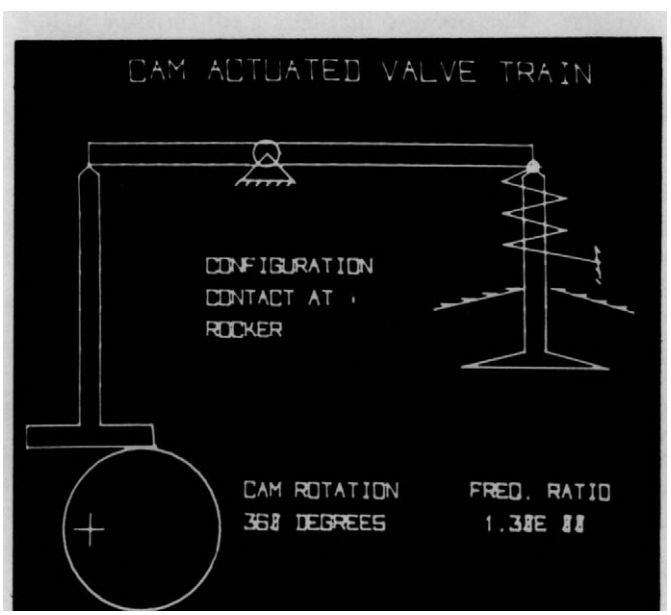

Figure 2 – Cam-actuated valve train animation

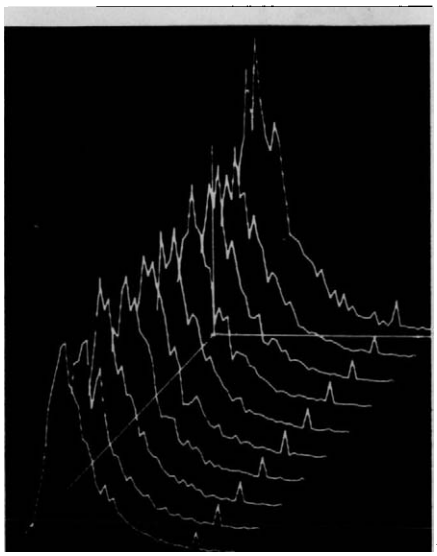

Figure 3 – Energy spectrum of nonstationary noise vs. time contour

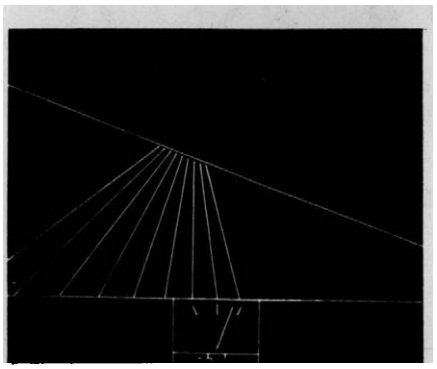

Figure 4 – Pilot's cockpit inside-out view in a spin simulator.

Figure 5 – Naval air-to-surface tactical war game

is impossible without pictures at all. Therefore, the limited space available will be devoted for the most part to pictures selected to illustrate one or more of five classes of simulation problems: The presentation of physical operations or phenomena which cannot be observed in the real system; models developed for operator training; gaming models; models of systems where cost, complexity, or time scale preclude experiments on the system; and design and synthesis tools.

Figure 2 is an example of the use of animation to allow visualization of operations not visible in the real system. The model allows for the variation of both physical dimensions and the characteristics of the materials. The display includes a continuous motion of the parts, as well as an accentuated deflection of the rocker arm and compression and elongation of the rods under stress.[3] The next figure is a projection of the energy spectrum of nonstationary noise as a function of time. The resulting contour clearly reveals a source of coherent energy as a ridge. This system finds application in presenting the phenomenon itself and also as a means of using human operators as signal detectors. The wide applications of simulation tools is exemplified by the use of this projection for the study of the heart rate of ground squirrels.

Programs in aeronautics at the school have centered on the development of useful presentations for aircraft trainers. Figure 4 shows a presentation of a horizon, reference lines, and an instrument group for a spin simulator.[5] A similar program was developed for a carrier-landing trainer. In both cases the dynamics of existing and postulated aircraft were mechanized on the hybrid/analog computer. The display reacts in real time in response to cockpit controls.

The next two figures are examples of the use of graphics in operations research. While both represent examples from war gaming, similar conditions apply to business games.

Figure 5 represents a display developed for the evaluation of tactical command and control. The simulation presents by animation the attack of an aircraft against a ship armed with surface-to-air missiles. The effect of radar range on the distribution of detection range, speed of aircraft, and evasive maneuvers can be evaluated.[11]

An interesting means of studying underwater sound propagation is shown in Figure 6. For a given sound velocity profile as a function of depth, a ray path is

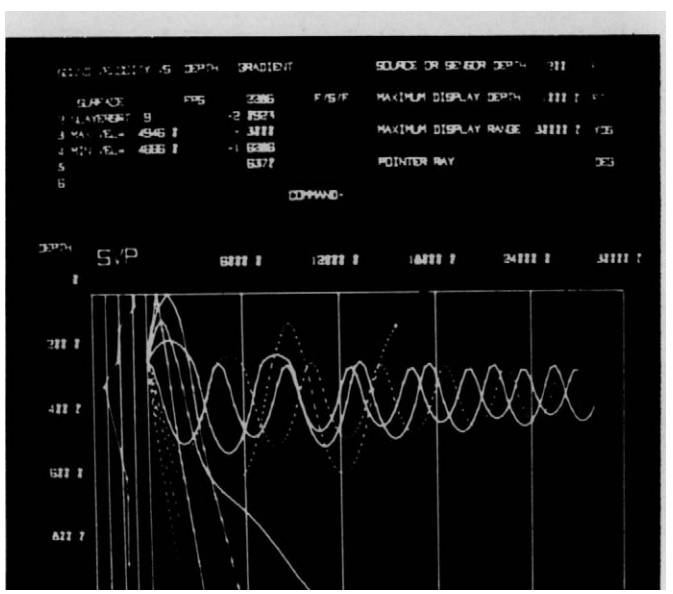

Figure 6 – Acoustic ray-path trajectories for a selected sound velocity Profile

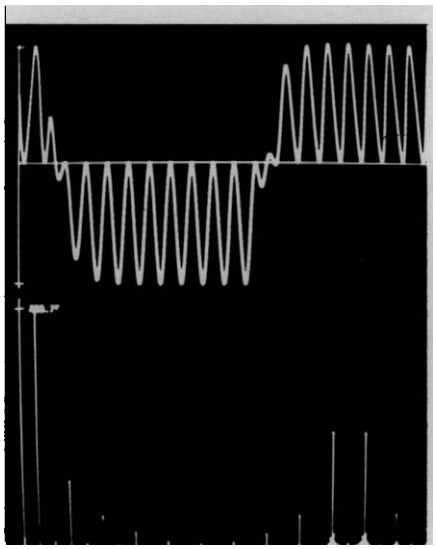

Figure 7 – Demodulated PSK modulated signal-time and frequency displays

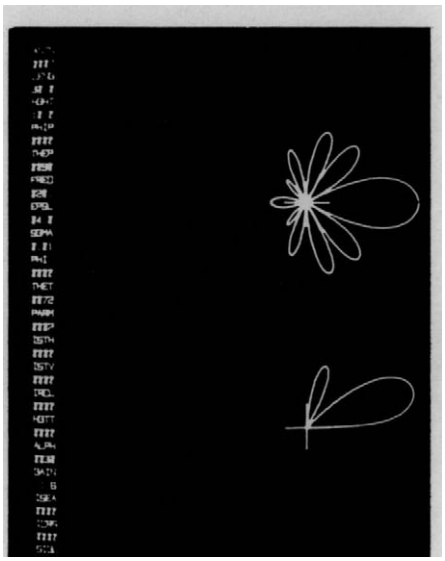

Figure 8 – Horizontal and vertical rombic antenna patterns

displayed at five degree intervals. The depth of the source of the sound may be varied continuously. This program was developed as an aid to tactical decision-making and has continued as a tutorial tool in acoustics, where the subject predicts performance and then allows the program to verify the results. Similar programs to rapidly examine the consequences of a large number of possible actions lend themselves to business games. The presence of two graphics terminals in the system allows these tactical or business games to be carried out between opposing teams in real time.

Perhaps the most common objects of simulation are complex systems where cost and the fixed configurations of the real system preclude ready experimentation. The following examples are drawn from large systems involving signal analysis.

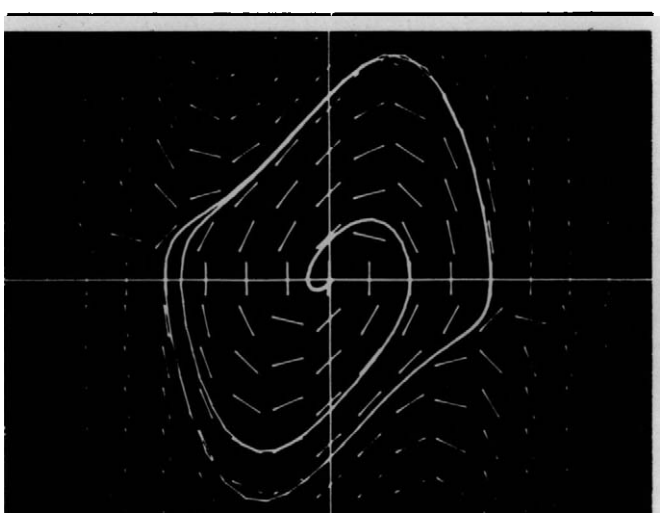

Figure 9 – Phase-plane analysis

Exploration of problems in signal analysis and synthesis is a major field for computer graphics. This follows from the fact that generally only a few special cases lend themselves to other than computer solution, and secondly there is much to be gained from visualization in this area. Figure 7 shows a demodulated phase-shift-keyed (PSK) signal in the time domain with the accompanying energy spectral density. The effects of filtering and channel noise are only two of the possible parameters which can be studied in this hybrid simulation of a number of modulation systems.[16] An example of the use of this technique for both research and instruction in a large engineering system was provided by a hybrid simulation of a complete sonar system. Ease of parameter variation and the evaluation of total system effectiveness for alternate mechanizations characterize this technique.[8]

The key to effective use of graphics in design is maintaining the operator's concentration by fast response of the display. The application of interactive graphics to the design of an antenna is illustrated in Figure 8. A menu of parameters which may be varied can be seen on the left side of the picture, the resultant horizontal (top) and vertical patterns are shown. For any given set of parameters, the effect of ship's motion on the antenna pattern can be displayed, as a function of sea state.[10]

Another design program provides for the study of a four-bar linkage systems.[4] In this case the operator varies the length and pivot points and watches as the path of any selected point is drawn on the display. Still another program provides for the design and comparison of lens and holographic-type acoustic image systems.[14]

The next figure is typical of the output of many graphics-oriented simulation-analysis tools. Here the operator not only comes to understand the system, but also gains new insight into the analysis tools themselves. Figure 9 presents a field of point slopes in the phase-plane for a specified equation. The operator may then select the initial conditions with a light pen and observe the resulting phase plane as it is generated. In the study of control systems a root locus can be generated for any set of open loop poles and zeroes. The operator can describe his system from cards or by light pen at the terminal. The plot may be stopped at any point and the value of gain presented for that location of

the closed-loop poles. Again, the operator can benefit from the autoinstruction provided by predicting system performance and observing the true results.

Other examples of simulation analysis tools include program to fit curves to data points,[9] which have found wide application, and programs for circuit analysis and synthesis.[17]

A dramatic example of analysis was provided by the identification of signals made up of as many as two thousand spectral lines by the real-time variation of twenty interrelated parameters in a mathematical model of complex electron spin resonance spectra.[15] In this application the operator's humanistic abilities are combined with the algorithmic properties of the machine in a true symbiotic union.

CONCLUSION

While the use of graphics and man-machine interaction covers a wide spectrum of application, by far the most exciting is the prospect of even better use of the machine in the problem-formulation process: the goal — to move from manipulating symbols to understand relationships.

The way to a man's heart may well be through his stomach, but the way to a man's understanding is through his eyes.

ABOUT THE AUTHOR

George A. Rahe is an Associate Professor of Electrical Engineering and Director of the Naval Postgraduate School Computer Laboratory. Prior to coming to NPS he was associated with UCLA and TRW Systems. His primary research interest and that of his laboratory is simulation and man-machine interfaces.

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